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ADVANCEMENT OF CHINA'S VISIBLE LIGHT REMOTE  
SENSING TECHNOLOGY IN AEROSPACE

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## **ADVANCEMENT OF CHINA'S VISIBLE LIGHT REMOTE SENSING TECHNOLOGY IN AEROSPACE**

(Romanized title: *Wo Guo Hangtian Kejianguang Yaogan Jishu Yueshang Xin Taijie*)

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**Abstract:** Aerospace visible light film systems were among the earliest space remote sensing systems to be developed in China. They have been applied very well. To this date, Institute Number 508 has successfully developed three models for two generations of aerospace visible light cameras. This not only makes China the third nation in the world to master space remote-sensing technology, it also puts recoverable remote sensing satellites among the first kinds of first- and second-generation application satellites to be launched and achieve a breakthrough in China.

### **1. General Description**

On August 9, 1992, China successfully launched a new-model scientific research and technological experiment satellite. This satellite was a recoverable remote-sensing satellite equipped with a second-generation aerospace visible light remote sensing system developed by Institute Number 508. After this satellite was in normal orbit in space for 16 days, it returned according to schedule and landed safely in the predetermined area, having captured remote sensing information that was more accurate than ever before. This accomplishment indicated that China's space technology had begun to pass from the first to the second generation of application satellites and that it had entered a new stage where the primary goal was to improve satellite performance and expand satellite applications. In addition, it showed that China's aerospace visible light remote sensing technology had risen to new heights.

The special-purpose system of the recoverable remote-sensing satellite — the visible light film system — was one of the earliest space remote sensors developed in China. This system is composed of a surface feature camera, a stellar camera, a dark passage<sup>1</sup>, a film magazine, and other parts. Of these, the surface feature camera is used to shoot pictures of a predetermined area below its orbit, and to collect remote sensing information on the surface landscape; while the surface feature camera is operating, the stellar camera takes pictures of the stars synchronously, in order to correct for the satellite's attitude error afterwards. Film shot by these two cameras is conveyed through the dark passage to the film magazine, where it is stored and hermetically sealed. After the satellite completes its scheduled photographic mission, remote sensing information is obtained by retrieving the reentry module which holds the film magazine. This remote sensing method records and shows target images on photosensitive film, and has several advantages: its results can be perceived directly, it takes clear pictures which are easy to interpret, and its surface resolving power is quite high. It is a frequently-used and highly valuable space remote sensing method.

China began to study aerospace visible light photography systems in the latter half of 1967. By August 9, 1992, with camera researchers from this institute as the main research team, China had overcome many difficulties, including a lack of resources, insufficient experience, and simple and crude conditions, to complete development tasks for three models and two generations [of these systems]. These systems obtained a large amount of remote sensing information in 14 orbital flights by recoverable satellites, and made China the third nation in the world to master space remote sensing technology.

Of these two generations and three models of aerospace visible light photography systems, surface feature cameras passed through the development stages of prismatic scanning panoramic cameras and frame surveying cameras to nodal point panoramic cameras. A major indicator of the superiority of the performance of later cameras over previous models is that at the same orbital altitude, the surface resolving power of later cameras was greater by two to three times. The stellar photographing power of the stellar camera rose from only being able to measure magnitude 4 stars at the very beginning to causing magnitude 8 stars to show up on film, causing magnitude 7 stars to appear completely, and being able to measure magnitude 6 stars by 1988. Not only did the film-holding capacity of the film magazine increase by a large margin, the film magazine also became so airtight that once, one was submerged in water for seven days and

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<sup>1</sup> This word, *andao*, was not in any dictionary. This is its literal meaning.

seven nights without leaking (thus ensuring that the film inside was undamaged).

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## 2. Technological Hurdles and Progress

The prismatic scanning panoramic camera was the first kind of surface feature camera used by China as a first-generation visible light photographic system. This kind of camera has a large area of photographic coverage, dense structure, rapid scanning speed, and other advantages. But because the camera depends on the synchronous operation of the prisms and film to ensure image clarity, because two prisms must be placed in front of the lens to achieve panoramic photography, and because errors in the manufacture and assembly of prisms are unavoidable, its image quality is not only decided by the synchronous accuracy of film conveyance speed and image drift speed caused by prismatic scanning during filming; in addition, image resolving power is also affected by relative camera aperture decrease caused by the prism and double images formed on the image plane. Although the photographic quality of this kind of camera is not as good as that of other models of panoramic cameras with similar optical parameters, this camera has a relatively low level of development difficulty, and it was an appropriate choice as a breakthrough [in the area of satellite photography in China].

After the initial prototype of the prismatic scanning panoramic camera was assembled in spring of 1969, research and development personnel conscientiously analyzed places where problems appeared in the initial prototype camera testing stage and made design improvements. They skillfully solved many key technological problems, such as low-speed line crawl appearing in the prism mechanism, the inability of the camera to form images, the film storage mechanism jamming, frequent film pile-up in the film conveyance system, the inability of the body tube to meet airtightness requirements, severe deformation of the outer walls of the retrieval film magazine and dark passage, and the inability of the sealing and closure mechanisms to fulfill performance requirements. In this way, they ensured the normal operation of the camera. In the period from June 1970 to 1972, the initial prototype camera passed several rounds<sup>2</sup> of surface tests. At the beginning of 1973, upon entering the main prototype development stage, research and development personnel used prism temperature gradient tests, photographic aperture mechanism simulation tests, aperture temperature field tests, aperture pressure differential tests,

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<sup>2</sup> A literal translation of "zheng xing de" yields "whole stars of." In this context, "rounds of" seems more logical.

elimination of prism vibration and speed synchronization tests, and overall space photographic tests to verify that the quality of the main prototype satisfied design target requirements, and in June 1974 submitted the first camera product that could be launched. On November 26, 1975, China carried out its first successful launch of a recoverable remote sensing satellite. After the satellite operated normally in orbit for three days, it returned to earth. Since the thermal reentry plan had not been perfected, part of the structure of the reentry module burned up and crash landed, resulting in partial damage to the film magazine that was recovered. However, development of the film showed that the camera operated well and the pictures taken were clear. China's aerospace visible light remote sensing technology was off to a good start.

While filming, the direction of the light axis of a frame surveying camera does not change. It uses a start-stop shutter to focus target images in the lens viewing field on photosensitive film, and can provide large viewing-field angle images. The images have a strict geometrical relationship, and are often used in making survey maps. The focal length and [film] width<sup>3</sup> of the frame surveying cameras developed by China that are used in aerospace photography can compare favorably with the wide [film] width cameras on America's space shuttle and the European Space Agency's Spacelab, and its design targets approach those of the surveying cameras in Spacelab. Developing a satellite like this which meets requirements for a large viewing field, low distortion, high geometrical precision, and high space resolving power, and which can fulfill satellite structure restrictions, is an improvement in aerospace visible light remote sensing technology which required resolving several problems that are different from those involved with prismatic scanning panoramic cameras. Beginning in late 1979, research and development personnel methodically carried out experiments on several key technologies of this camera, such as the design of the large viewing field optical system, high-speed rotating central shutters, high-strength titanium alloy body tubes, measurement of high-accuracy internal azimuth elements, the vertical film-turning mechanism, the film-flattening mechanism, the image drift compensation mechanism, and the timing accuracy control of stellar and earth-surveying cameras. For example, the flattening mechanism must ensure that the film is in a flat state on the theoretical focal plane of the camera lens. Although the often-used platen method can give the film greater flatness, it increases image distortion and affects image quality. In order to both meet flattening requirements and not have detrimental effects on photographic results, research and development personnel decided to use a suction pump as a method to flatten film, and were able to successfully use this pump in a satellite module under low pressure conditions to flatten

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<sup>3</sup> Literally, *fumian* means "width of cloth." This is my best guess as to what it means in this context.

film and meet flatness requirements.

In February of 1983, after the frame surveying camera entered the initial prototype development stage, research and development personnel successfully solved many design, experimental, and technological problems. For example, the high-speed rotating central shutter, which has a large diameter, a high rotational speed, is very thin, and is required to be exposed synchronously with the stellar camera, went through repeated experimentation and modification before attaining the anticipated goals. Also, the titanium alloy body tube went through a series of technological measures before the many lenses in the body tube and the deviation and verticalness of the optical axis could fulfill design requirements.

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In September, 1987, the first time the frame surveying camera was used in a recoverable remote sensing satellite on an experimental flight mission, it obtained high-quality remote sensing information of the earth's surface. Thus, China stepped into the ranks of countries with advanced aerospace surveying cameras.

Nodal point panoramic cameras eliminate the scanning prism and avoid the problem of synchronous operation. This is an effective way of raising surface resolving power by a large margin. To improve China's aerospace visible light camera technology, research and development personnel began to carry out investigations of plans and principles of nodal point panoramic cameras in 1978, and fully completed preliminary research tasks between 1980 and 1986. During this period, through development of a sample camera, they solved many problems in succession, such as installation and adjustment of the lens, accurate determination of back nodal point positioning, debugging of the synchronous shutter curtain, adjustment of the film conveyance system, installation and modification of the platen, debugging of the air-suction flattening system, and coordination of camera photomechanical and electrical operations. Also, they tested and verified the camera's design principles, operating situation, and photographic quality through ground photography experiments and airborne photography experiments. Because preliminary research work on the nodal point panoramic camera was ample and sound, it laid the foundation for development plans for China's second generation of recoverable remote sensing satellites, and China successfully carried out an initial flight experiment mission within two and a half years.



In researching and developing the stellar camera, it was necessary to overcome the special technological problems brought about by weak light from the objects being photographed and strong parasitic light in the operating environment. Researchers first determined the exposure time and relative lens aperture of this kind of camera through ground experiments. Then, in view of problems such as film overexposure during flight experiments and inability of stellar photography capabilities to meet requirements, researchers made many improvements to the structure of the camera's photographic window<sup>4</sup>. This made the stellar camera program more rational and let quality targets for stellar photography make strides to world advanced levels.

### 3. Applications of Photographic Achievements

China's progress in aerospace visible light remote sensing technology let its satellite surveying system lead the way into the application stage at the beginning of the 1980s. The tens of thousands of meters of satellite photographs taken by 14 recoverable remote sensing satellites, which were processed, interpreted, and explained by national economic, military, and scientific departments, obtained a great deal of earth remote sensing information that would have been difficult or impossible to gain by other means. They have provided a scientific basis for the nation to formulate long-term national economic development plans and to carry out macroeconomic policy decisions. They have also changed traditional work methods and operation patterns, saved a great deal of manpower, material resources, and funds, and thus have clearly gained beneficial results. This information has been widely used in mineral and petroleum prospecting, earthquake geological analysis, coast and island surveying, port and river constructions, selection of railroad and highway lines, selection of sites for large-scale projects, topography mapping, archaeology of historical remains, farming and forest conditions, water resources, land utilization, surveys of territorial area, urban planning, environmental protection, national defense construction, and other fields. During the past several years, some departments have used this remote sensing information very effectively to carry out territorial resource and environmental composite surveys of seven areas, including the Beijing-Tianjin-Tangshan area, the Tarim Basin, and the Yellow River delta. Vice Chairman Ye Jianying in his written comments of March 1977 said that "Recoverable remote sensing satellites have performed great service," thus stating highly succinctly that recoverable remote sensing satellites and visible light photographic systems have played an important role in the cause of China's socialist modernization constructions.

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<sup>4</sup> Could also be "iris" or "aperture."

#### 4. Conclusion

After the successful launch and retrieval of the second-generation recoverable satellite, upper-level leaders of relevant departments commented in speeches at a victory meeting that "remote sensing information" "was extremely valuable." Their appraisal meant that remote sensing information had "reached a new level," and that they gave their full approval to this institute.

In addition to the three kinds of visible light remote sensing systems mentioned above, this institute is today carrying out preliminary research and development work on new remote sensing systems such as aerospace visible light remote sensing systems with better performance and higher surface resolving power, infrared-visible light multiple-spectrum scanning instruments, and solid charge-coupled device (CCD) cameras, and has achieved positive results by stages. The successful research, development, and deployment of these new remote sensing devices will raise China's aerospace remote sensing technology to new heights.

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